Development of Off-Axis Calibration Systems for KamLAND

K.M. Heeger, S.J. Freedman, M. Galloway, K.-B. Luk, and H. Steiner for the KamLAND Collaboration

In the past year KamLAND reported first evidence for reactor anti-neutrino disappearance based on the observation of an apparent deficit in the flux of $\overline{\nu}_e$ from nuclear power plants in Japan [1]. The observed deficit in the reactor neutrino flux is consistent with the hypothesis of neutrino oscillation, and the oscillation parameters are in agreement with the large-mixing-angle MSW solution to the solar neutrino problem [2]. None of the neutrino experiments to date has observed a direct signature of neutrino oscillations and one of KamLAND's primary physics goals is the search for distortions in the reactor neutrino energy spectrum as a unique signature of neutrino oscillations.

A precision measurement of the reactor neutrino energy spectrum requires a detailed understanding of the detector response to $\overline{\nu}_e$ interactions throughout the entire detector volume and high statistics in the number of detected reactor neutrinos. At present KamLAND is calibrated using ^{68}Ge, ^{65}Zn, ^{60}Co, and Am-Be sources deployed along the z-axis of the detector. Combined with the characteristic signatures of spallation products and neutron capture on protons and ^{12}C, these sources are used to determine the detector's energy response, its uniformity, and reconstruction characteristics [1].

More detailed detector studies require off-axis calibration systems combined with multiple calibration sources. They will allow KamLAND to test the energy response $E(r, \theta, \phi)$ as well as the reconstruction characteristics $R_{fit}(E, r, \theta, \phi)$ of the detector as a function of position and energy inside the active detector volume. Off-axis calibrations will (a) determine precisely the number of target atoms inside the reconstructed detector volume, (b) increase the fiducial volume and hence the $\overline{\nu}_e$ interaction rate, and (c) verify the uniformity and linearity of the energy scale as inferred from calibrations along the z-axis and from muon spallation products.

Two different source deployment systems are under development to achieve this next step in the KamLAND calibration program. Both systems use the KamLAND CCD camera system and infrared LEDs for real-time position monitoring and off-line reconstruction. In-situ tests in early 2003 demonstrated that infrared LEDs are an effective tool for monitoring calibration systems during deployment while allowing precise off-line position reconstruction with an accuracy of < 3 cm.

One of the off-axis calibration systems under development uses a segmented stainless steel pole of variable length with calibration sources attached to its end. The pole is assembled inside the glovebox and lowered into the central detector region while suspended from two control cables. The system is designed for deployment through the glovebox which provides access to the inner detector region. The calibration pole allows the use of two identical or different calibration sources and provides excellent source positioning in θ and r.

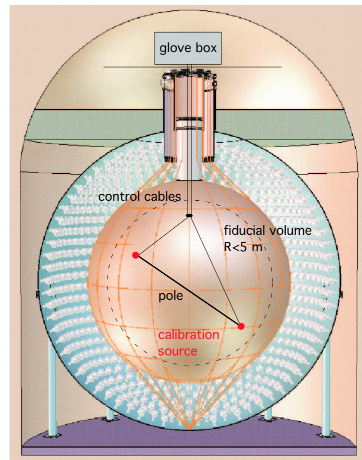

FIG. 1: Schematic of an off-axis calibration pole system for the KamLAND detector. Two calibration sources attached to a segmented pole are positioned near the boundary of the fiducial volume with two control cables.

As a parallel R&D effort, the concept of a remotely operated submersible vehicle (ROV) for detector calibration and inspection is investigated. The use of a ROV in a neutrino detector was pioneered by the SNO experiment for the installation of detector components. It provides the most flexible and least invasive way to access all regions in the inner detector. A commercial ROV system from *VideoRay* [3] is being evaluated for its compatibility with the stringent cleanliness requirements, and development of a customized positioning system is underway. The successful development of a cleanroom-compatible, multipurpose ROV system will provide KamLAND with a novel inspection and calibration system and will be of use for very large particle detectors envisioned for future proton-decay or long-baseline neutrino experiments.

[1] K. Eguchi et al. (KamLAND Collaboration), Phys.Rev.Lett.**90**:021802 (2003)

[2] J.N. Bahcall, M.C. Gonzalez-Garcia, and C. Pea-Garay, JHEP 02(2003)009, hep-ph/0212147 (2002)

[3] VideoRay, http://www.videoray.com/.